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SATELLITE RADIO POSITIONING COMMUNICATIONS SYSTEM
SIGNAL TRANSMISSION SYSTEMS

by

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ABSTRACT A type of signal transmission system appropriate for use in satellite radio positioning communications systems is introduced, pointing out several key technological problems and solution methods with the signal transmission systems in question.

1 SUMMARY

The principal advantage of making use of satellite systems to carry out positioning and navigation lies in the broad range of coverage and long effective ranges, thereby providing extremely great flexibility for the selection of frequencies and signal structures. The advent of GPS satellite navigation systems meant that satellite navigation technology had entered a more advanced development phase, receiving the attention of military and civilian departments of various nations. Following along with the development of science and technology--in particular, computer technology, which had already deeply entered into various realms of society--civilian departments all required the supplying of positioning and navigation and even communications services in order to increase benefits and the automation of management. People have done broad research on civilian satellite navigation systems [1]. Opting adequately for the use of advanced technology which currently exists and primarily considering capabilities in both the areas of positioning and communications performance, it is possible to obtain systems associated with multiple types of application functions and economical in actual use. We take this type of positioning system, which has communications functions as well, to be a satellite radio positioning communications system.

Satellite radio positioning and communications systems are primarily composed of three parts--central ground station (simply called the central station), space satellites, and user terminal equipment (called user devices). The main differences from GPS lie in the two areas that follow. First, due to the fact that the systems in question possess communications functions, as a result, it is no longer that GPS type of open loop system associated with passive reception and is a closed loop system. Users must, first of all, capture broadcast information sent out by the central station. After that, it is transmited, going through satellites and reaching the central station, after which, by central station calculations, user position (speed) information is then obtained to give to users. Second, the positioning calculations associated with the systems in question are completed by the central station. It is possible to make user devices become very simple. GPS is not this way, however.

These characteristics resolve peculiarities associated with satellite radio positioning and communications system signal transmission systems as well as technological difficulties. Below we will present a type of signal transmission system which is appropriate for use in association with satellite radio positioning and communications systems. In conjunction with this, explanations will be made with respect to several key technologies associated with the signal transmission systems in question.

2 SIGNAL TRANSMISSION SYSTEMS

The basic starting point associated with satellite positioning and communications systems is with a view toward civilian uses. The main manifestations are that: first, the central node type network topological structure, equipment, and technological difficulties are concentrated as much as possible in the central station, making use of user devices which are as simple as possible. Second, user active positioning. This is due to the system having both positioning and communications functions. Moreover, there is a requirement for all positioning calculations to be completed by the central station. Third, user numbers are several hundred thousand or even more. Option is made for the use of direct sequence expansion frequency spectrum type transmission of subgrouped data, making use of pseudo random modulation of expansion frequency ranging [2]. Ranging precision depends on the code speed of pseudo random codes selected. When code speeds reach around 10Mb/s, ranging accuracies can reach the meter level. Besides this, speaking in terms of expansion frequency methods with regard to communications, receivers are capable of achieving deexpansion gains of several tens of decibels. As a result, signal power spectrum densities required are very low, thus lowering requirements with regard to satellite transmiters and antenna dimensions. Below, we make further explanations, dividing up several areas with regard to transmission systems.

2.1 Station Entry Link Circuits

Station entry link circuits refer to link circuits from user devices through satellites to central station recievers. Station entry link circuits are one type of expansion frequency/random cut in/time division multiple use communications (SS/AA/TDM). Its characteristics are:

(1) Signals entering stations are expansion frequency burst short pulse signals. Instants when signals reach central receivers are arbitrary and random. /10

(2) In systems, signals associated with different users entering stations are capable of "reaching the central station at the same time". Even if use is made of pseudo codes which are completely the same, so long as pseudo codes are staggered a certain number of code section phases, the central station is then capable of simultaneously carrying out reception and processing with regard to them.

(3) Signals coming into stations are sent out from user devices. They go through two satellite or three satellite relays and are transmited to the central station, acting as the positioning foundation.

Requirements on the central station with regard to the processing of station entry signals are, first of all, to carry out capture of pseudo codes within a very short period of time (5.5ms), and, in conjunction with this, to complete delay lock in

tracking with regard to pseudo codes as well as selection and lock in with respect to carrier waves; next, to carry out deexpansion and demodulation with regard to signals, and, in conjunction with that, complete signal decoding (Viterbi decoding). After that, on the basis of data, positioning and communications processing is carried out with respect to information and time measurement data. As a result, station entry signals possess the special structure shown in Fig.1

Synchronous guidance sequences are special short pseudo code sequences set up to carry out capture with respect to long code. There are three roles associated with tracking sections. The first is precision lock in in order to set up delay lock in loops DLL with regard to expansion frequency pseudo codes. The second is to set up lock in with respect to carrier waves. The third is to make use of UW (Unique Word) to eliminate BPSK carrier wave ambiguities.

2.2 Link Circuits Leaving Stations

Link circuits leaving stations refer to central station link circuits going through satellites to user devices. The transmission method associated with link circuits leaving stations is to opt for the use of time division multichannel data package cascade forms. As far as so called information package cascade transmission methods are concerned, they refer to users, in communications sections, being able to randomly share, thereby--in terms of time--fully making use of communications sections in subframes in order to increase systems communications capacity. With respect to signals leaving stations, each 16.384 ms constitutes one frame. Each frame has a frame number. Frame structure is fixed. One superframe is composed of 216 = 65536 frames. Frame numbers cycle from 1 to 65536. In this way, signals leaving stations then possess high resolution nonambiguous time graduations in order to provide the foundation for ranging.

Standard package formats for signals leaving stations satisfy high level data link circuit control (HDLC) regulations. In them are also included a certain number of individual data packages. Within one frame, it is possible for there only to be one user sending data. It is also possible for there to be n users sending data. However, these users must be of the same type. Frame structures leaving stations are as shown in Fig.2.

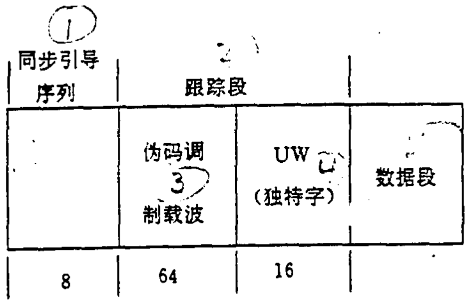

Fig.1 Station Entry Link Circuit Frame Structure

Key: (1) Synchronous Guidance Sequence (2) Tracking Section (3) Pseudo Code Modulation Carrier Wave (4) Unique Word (5) Data Section

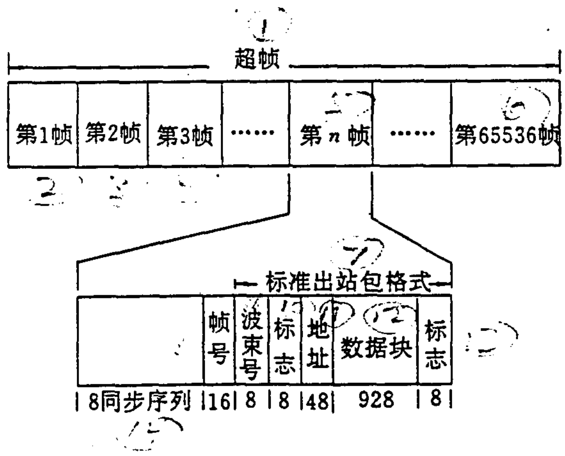

Fig.2 Frame Structure Leaving Stations

Key: (1) Super Frame (2) First Frame (3) Second Frame (4) Third Frame (5) Nth Frame (6) 65536th Frame (7) Standard Package Format Leaving Stations (8) Frame No. (9) Beam No. (10) Marking (11) Address (12) Data Block (13) Marking (14) Synchronous Sequence

2.3 Pseudo Code Selection

Satellite positioning and communications systems--it goes without saying--opt in the case of both station entry and frames leaving stations for the use of synchronous guidance sequences to assist in capture. As a result, pseudo code selection includes the selection of synchronous guidance short codes as well as the selection of address codes.

Due to the fact that central stations opt for the use of passive matching wave filter devices to act as auxilliary synchronicity systems, it is possible to rapidly supply address code reference phases, making receiver reference address codes and receiver signal address codes synchronous. As a result, synchronous guidance sections can select relatively long pseudo codes in order to increase processing gains. On the basis of Chinese SAW equipment development levels at the present time, 255 digit m sequences are selected.

In expansion frequency spectrum communications, the selection of address codes is extremely important because such things as the address code types, code period lengths, as well as code clock speeds, and so on, directly influence system performance. Standards for selecting address codes used in direct sequence expansion frequency systems are: (1) Good autocorrelation characteristics and mutual correlation characteristics. The reason is that this type of address code is capable of making mutual interference betwee various address codes small. Moreover, it is advantageous for initial receiver synchronicity and tracking with respect to signals. 2) Code period lengths must be able to satisfy requirements associated with interference limits. In conjunction with this, they should be able to make signals possess uniform dispersion of /11 frequency spectra. 3) There must be adequately large code groups to provide simultaneous utilization. 4) For convenience of capture, be able to make reception signal initial synchronicity periods relatively short. 5) Be easy to actualize.

In satellite positioning and communications systems, option is made for the use of synchronous guidance sequences to carry out capture. Comparing a few types of commonly used code forms, we adopted Gold code. Gold code is composed of two m sequence codes with the same length and minimal maximum mutual correlation values carrying out, digit by digit, two phase mode addition. Altering the relative phases of the two m sequences producing it, it is then possible to obtain different codes. With regard to length, the m sequence is M=2n-1. Each two codes are capable of making use of this method to produce M Gold sequences. Among these M codes, the maximum mutual correlation values between any two are equal, in all cases, to the maximum mutual correlation values associated with those two m sequences composing them. Gold code autocorrelation side lobes show fluctuations. However, the peak values do not exceed maximum values for mutual

correlations. The number of addresses which Gold codes are capable of simultaneously using is large. Therefore, they are widely used in multiple address expansion frequency communications.

2.4 Military Security Measures

Satellite positioning communications systems are a type system which is primarily for civilian use. In order to let military users make use of them to good effect, it is necessary that they possess corresponding security measures associated with signal transmission and reception in order to guarantee--during the process of reception by lawful users--not being intercepted by third parties. Moreover, speaking in terms of signals coming into stations, the burst nature of transmissions is even more advantageous to information security. However, speaking with respect to professional code breakers, this type of transmission is certainly not secure. There is need for the adoption of professional security measures.

As far as characteristics of combined system signal transmission systems are concerned, with respect to military users, option is made for the use of two types of security methods at the same time--signal security encryption and data security encryption. On the basis of satellite positioning communications system standards, signal expansion frequency encryption sequence code speed is 8Mb/s. Code length is 217-1. Code forms can be m sequence and Gold sequence. As far as opting for the use of m sequence state wave filter sequences to act as signal expansion frequency codes is concerned, generally, user data is still Gold sequence expansion frequency. As far as data security encryption is concerned, in the same way, option is made for the use of running secret codes, formed by rolling code key generators from m sequence nonlinear prefeed sequences. Due to the length of information subgroup frames, selection is made of appropriate lengths associated with m sequence generators, making code breakers unable to completely obtain the needed estimate values, increasing security a step further.

3 SEVERAL KEY TECHNOLOGIES

3.1 Capacity Increase Technology and Multiple Reception

In central station expansion frequency receiver random multiple address signals entering the station--due to signal collisions created by multiple reception and contradictions associated with multichannel equipment capabilities--they will be an important factor influencing system user capacity. The results of research associated with user capacity models clearly show that [3] increased demodulation modules are capable of making the handling capacity associated with station entry link circuits greatly improve. This then requires that central station receivers possess relatively strong parallel processing

capabilities. Two key problems must be promptly solved. One is multichannel signal recognition and separation. The second is real time reception of multichannel data. The line and block diagram for multichannel reception systems is as shown in Fig.3.

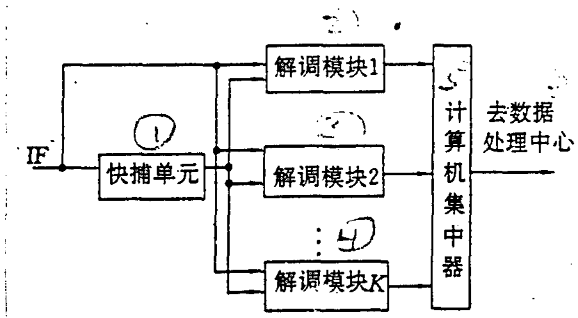

Fig.3 Multichannel Reception System Line and Block Chart

Key: (1) Quick Capture Unit (2) Demodulation Module 1 (3) Demodulation Module 2 (4) Demodulation Module K (5) Computer Intensifier (6) Out to Data Processing Center

Due to opting for the use of special synchronous guidance sequences, when collisions are generated between the frames of multiple users, in terms of theory, so long as synchronous sequences are staggered two code sections it is then possible to receive correctly. Recognition and distribution units complete recognition of this type of synchronous sequence. In conjunction with this, various frames are taken and distributed to K channels of parallel demodulation modules. K channels of demodulation modules complete with respect to pseudo codes such functions as tracking, deexpansion, demodulation, and pseudo code survey, and so on. In conjunction with this, K channels of data information are taken and sent to computer data intensifiers. So called computer data intensifiers are nothing else than the compression and storage of data coming from multiple terminals. In conjunction with this, they are sent onto a high speed trunk line in order facilitate entry into main computers. Their characteristics are that transmission terminals only have one channel. The capacity of the channel in question must be /12 lower than the sum of the capacities of input terminals. From station entry frame structures, it is possible to know that synchronous header and administrative sections have no use after demodulation and are lost. As a result, time gaps associated with this section are free. Besides this, random cut in methods create randomness associated with time utilization of K parallel channel demodulation modules. There are large amounts of free time. Intensifiers take data with high utilization and use it to substitute for these low utilization rate data and obtain economic benefits.

3.2 Expansion Frequency Code Capture Techniques

In order to detect signals, receivers associated with direct sequence expansion frequency systems must make receiver reference address codes and address codes of received signals match up in phase. Only in this way is it then possible to go through phase multiplication to eliminate useful signal frequency spectrum expansions. This synchronous process is generally divided into two phases--capture and tracking.

Above, we have already talked about the fact that satellite radio positioning communications system station entry link circuits are a type of expansion frequency/random cut in/time division multiple use channel. Signals entering stations are expansion frequency burst short pulse signals. The instants that signals arrive at the central station receivers are random and multiple. Moreover, signal to noise ratios are very low--on the order to -18---20dB. As far as the capture of this type of low signal to noise ratio multiple burst signal is concerned--seen in view of the technological level at the present time--difficulties are very great. As a result, it is possible to say that expansion frequency code quick capture technology is the key to the success or failure of the entire system's signal transmission system.

Central station receivers must--in medium frequencies--complete the capture of expansion frequency codes. Application of surface acoustic wave (SAW) matching wave filter devices can be said to be one type of unusually ideal technology. However, being limited by SAW technology, synchronous guidance sequences made use of are generally relatively short. Processing gains are small. With low signal to noise ratios, synchronicity leak probabilities and false synchronicity probabilities are both very great, causing there to be no way to synchronize reliably. Here, we put forward one type of synchronous guidance sequence designated as position encryption. Under low signal to noise ratio conditions, it possesses good synchronicity characteristics. At the same time, it resolves quick capture problems associated with multiple burst signals very well.

3.2.1 Synchronous Guidance Sequence Position Encryption

Assuming that synchronous guidance sequences are m sequences of code length L, using m sequences associated with 4 groups that are the same to carry out phase encryption, synchronous sequences after encrytion are as shown in Fig.4. The encryption method is to insert a code section P1 between the first m sequence and the second m sequence. A P2 code section is inserted between the second m sequence and the third m sequence. A P3 code section is inserted between the third m sequence and the fourth m sequence. Moreover, $P_i \neq P_j$ $(i,j = 1,2,3)$. As far as the guidance sequence modulation discussed above is concerned, at radio frequencies, application is made of SAW matching wave filter devices to carry out capture of them. Capture circuits are as shown in Fig.5. After going through envelope wave detection and gate limit decision circuits, correlation peak widths are one code section pulse. As a result, S4(t) patterns are pulse sequences. The local autocorrelation functions are as shown in Fig.6. From the

local autocorrelation functions of Fig.6, it is possible to

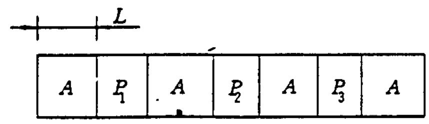

Fig.4 Synchronous Sequence Possessing Position Encryption

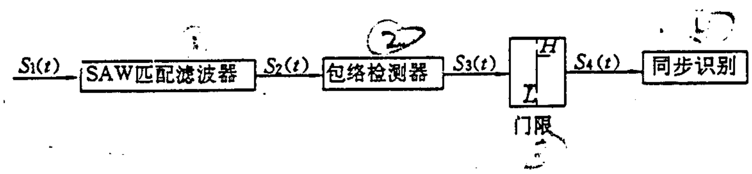

Fig.5 Synchronous Capture Circuit

Key: (1) SAW Matching Wave Filter Device (2) Envelope Detector (3) Gate Limit (4) Synchronous Identification

know that local autocorrelation functions associated with position encryption methods are clearly improved. It is possible to opt for the use of decision criteria associated with chosing 3 out of 4 or chosing 2 out of 4, thereby enlarging interference tolerance, improving synchronicity characteristics.

In order to further improve synchronicity characteristics, it is possible to increase the obtaining of repeating numbers associated with synchronous guidance sequences. Basic encryption principles are to make local autocorrelation function side peaks as small as possible. The systems in question opt for the use of encryption sturctures shown in Fig.7, that is, taking 16 m sequences and dividing them into 4 groups. Within the groups, Baka (phonetic) encryption is done on 4 m sequences. P1 , P2 , and P3 code sections are inserted, respectively, between the /13 groups. Side peak values associated with local autocorrelation functions of this type of postion encryption sequences are not greater than 4. As a result, it is possible to opt for the use

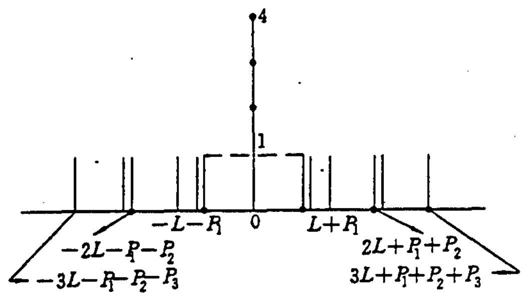

Fig.6 Local Autocorrelation Functions of Synchronous Sequences

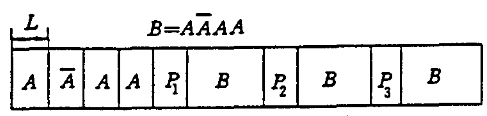

Fig.7 Synchronicity Structure Associated with 16 m Sequences

of decision methods associated with selecting (16-K) out of 16. In this, K is the permissible leak detection correlation peak number (K=0,1,2...,11). The largest K is 11.

3.2.2 Synchronicity Characteristics

Reference [4] gives analysis processes and results. Corresponding to the synchronicity structures of Fig.7, selection is made of m sequence code length L = 255. Assuming synchronicity probability is 10-4 , then, the encryption gain achieved by the encryption methods in question is approximately 7.6dB.

3.3 Data Processing Technology

The characteristics of satellite positioning communications system data processing are that--equiped with high capacity data bases--in order to realize real time positioning and communications processing, it is necessary to have relatively high processing speeds. As a result, the computer system set up which is needed can be a main frame system, and it can also be a dispersed type computer system.

In the systems in question, data handling processes are roughly as follows. Data flow coming from demodulation devices is taken and decoding is carried out. Data packages after decoding are taken and, in accordance with the shunt addresses which they carry in themselves, they are distributed, at as high a speed as possible, to the corresponding functional nodes. After that, such calculations as communications and positioning

are carried out. After completion of the necessary processing, the information which will be returned to the user will take a specially designated form made up as an information package. After encoding, it is sent to modulations devices. At the same time, storage is carried out on near term user information. In preparation for finding it, the necessary incident records and service records are made.

4 CONCLUDING REMARKS

This article introduced data transmission systems associated with one type of satellite radio positioning communications system based on expansion frequency technology. The several key technologies which are discussed in the article have already had research carried out on them in China for many years. In conjunction with this, great progress has been achieved. The main performance characteristics associated with quick capture of signals entering stations have already reached advanced international levels. These theoretical studies and the set up of experimental systems lay a good foundation for the implementation of engineering associated with the next steps.

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